# PROBE FOR SENSING THE POSITION OF AN OBJECT

BACKGROUND OF THE INVENTION

5    This invention relates to probes for sensing the
     position of an object.  It may be used on positioning
     apparatus such as machine tools, coordinate measuring
     machines, measuring robots and the like.

10   Particularly in numerically controlled machine tools,
     it is known to exchange a cutting tool for a position-
     sensing probe.  The probe may for example be of the
     touch trigger type, such as shown in US Patent No.
     4,153,998 (McMurtry), which is incorporated herein by
15   reference.  Such a probe has a workpiece-contacting
     stylus and issues a trigger signal when the stylus
     contacts a workpiece.  Alternatively, the probe may be
     of the "analogue" or "measuring" or "proportional"
     type, which provides an output which is a measure of
20   the deflection of the stylus relative to a body of the
     probe.  Rather than having a workpiece-contacting
     stylus, any of these types of probe may instead sense
     the workpiece using optical, capacitive, inductive
     (e.g. using eddy currents) or other non-contact
25   techniques.  The present invention may be used with any
     of these and with other types of probes.

     Since such a probe for use in machine tools is
     exchangeable with cutting tools, it can be difficult to
30   provide wires or cables to connect the probe's output
     signal to the controller of the machine.  Consequently,
     various wireless signal transmission techniques are
     used, including inductive transmission, optical
     transmission and radio transmission.  The probe then

**CONFIRMATION COPY**

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needs to be battery powered. To conserve battery life,
it is desirable that the probe should only be switched
on when in use.

5      A known technique for switching on such a probe is
described in US Patent No. 4,599,524 (McMurtry), which
is incorporated herein by reference. Here, after the
probe has been inserted in the spindle of a machine
tool, its battery is switched on by a brief rotation of
10     the spindle. A centrifugal switch within the probe
responds to such rotation. After use, the battery may
be disconnected by a further such rotation, or by a
delay element within the circuit of the probe which
times out after a predetermined period of non-use of
15     the probe.

Probes using such centrifugal switches have been
successful commercially, but the centrifugal switches
used are fairly bulky. Consequently, if a probe having
20     a small physical size is required, such centrifugal
switches cannot be used, and it has been necessary to
use other methods for switching the probe on. A
further problem with such centrifugal switches is that
they are relatively expensive.

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SUMMARY OF THE INVENTION

In broad outline, one aspect of the present invention
replaces such a centrifugal switch with a sensor which
30     is sensitive to linear acceleration. In a preferred
embodiment the sensor is in the form of a switch, but
other linear acceleration sensors may also be used.
Linear acceleration sensors are available commercially,
for example as switches intended for automotive use,

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and may be smaller and cheaper than the centrifugal
switches used in the prior art. Accelerometers which
provide a signal proportional to the acceleration may
also be used.

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Thus, this aspect of the present invention provides a
probe for sensing the position of an object on
positioning apparatus, comprising:
        a first electric circuit responsive to the probe
10   attaining a sensing relationship with the object;
        a power supply for energising said circuit;
        a sensor responsive to movement of the probe and
arranged to cause the power supply to be connected to
said circuit when movement is detected;
15         characterised in that said sensor is responsive to
linear acceleration.

Preferably said sensor is positioned in the probe such
that it is also responsive to rotation. Thus, after
20   the probe has been inserted into a rotatable spindle of
the position sensing apparatus, it can be rotated in
order to activate the sensor and thus switch on the
probe.

. 25   Where rotation is used to operate the sensor, a further
problem may arise in practice, as follows. The probe
may also be subjected to linear accelerations, which
could activate the sensor at unwanted times. This may
for example arise during the exchange of the probe
30   between the spindle of the positioning apparatus and a
tool storage magazine, or when such a storage magazine
itself moves while the probe is stored in it.

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Consequently, the linear acceleration sensor may be
connected to a discriminating circuit for
discriminating between linear acceleration and
rotation, connecting the power supply to the sensing
5      circuit when rotation is detected.

The centrifugal switch described in US Patent No.
4,599,524 is designed for use in a machine tool with a
spindle which rotates about a vertical axis.  This
10     leads to a further problem: it is not always reliable
if used in a machine tool having a spindle which
rotates about a horizontal axis.  The same would be
true if a linear acceleration sensor were used in a
horizontal spindle machine.  This is because gravity
15     varies the acceleration experienced by the sensor over
the cycle of the rotation about the horizontal axis.
At the bottom of the rotation, gravity acts in a
radially outwards direction, while at the top it acts
in a radially inwards direction.  A centrifugal or
20     other acceleration-sensitive switch would tend to
switch off for part of the cycle and on for another
part.  Other types of acceleration sensor would be
similarly affected.

25     A further aspect of the invention provides a probe for
sensing the position of an object on positioning
apparatus, comprising:
       a first electric circuit responsive to the probe
attaining a sensing relationship with the object;
30             a power supply for energising said first circuit;
       a sensor responsive to movement of the probe and
arranged to cause the power supply to be connected to
said first electric circuit when movement is detected;

characterised in that a movement-discriminating
circuit is connected to said sensor, the movement-
discriminating circuit discriminating a movement
indicating that the probe is to be used from other
5    movements.


The movement-discriminating circuit may be responsive
to receipt of a signal corresponding to a predetermined
signature relating to movement of the probe.

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Preferably the movement-discriminating circuit
discriminates rotation of the probe from linear
accelerations, connecting the power supply to the first
electric circuit when rotation is detected.

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In a preferred form, the movement-discriminating
circuit detects whether a signal indicating rotation is
received from the sensor over a period or periods of
time corresponding to only a part or parts of a full
20    revolution of the probe.


Thus, preferred embodiments of this further aspect of
the present invention improve the reliability of both
centrifugal and linear acceleration sensors when used
25    to detect rotation on horizontal spindle machines,
where the sensor may give a signal for only part of a
full revolution.


In one preferred embodiment of this further aspect of
30    the invention, the sensor may again be a switch.


In either aspect of the invention, the sensor may also
be arranged to disconnect the power supply from said
first electric circuit when a further rotation or other

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movement of the probe is detected.  Alternatively, a
timer may be provided which disconnects the power
supply a predetermined period after it was connected,
or after a predetermined period of non-use of the
5    probe.  The probe may have both these options for
disconnecting the power supply.

Preferably the power supply is a battery.

10   BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the present invention will now
be described by way of example, with reference to the
accompanying drawings, wherein:
15       Fig 1 schematically illustrates a probe installed
in a machine tool;
         Fig 2 is a vertical cross-section of part of the
probe of Fig 1;
         Fig 3 is a horizontal section on the line III-III
20   in Fig 2;
         Fig 4 is a schematic circuit diagram of part of
the circuitry within the probe;
         Figs 5,6, 7 and 8 are flow charts of parts of a
program which may run in a processor contained within
25   the circuit of Fig 4; and
         Fig 9 is a schematic circuit diagram of part of an
alternative embodiment.

DESCRIPTION OF PREFERRED EMBODIMENTS
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Referring to Fig 1, a touch trigger probe 10 has a
shank 16 for insertion into a rotatable spindle 14 of a
machine tool, in exchange for a cutting tool.  The
spindle can then be moved in three dimensions (in

directions X,Y,Z) relative to a workpiece (not shown)
in order to bring a stylus 12 of the probe 10 into
contact with various points on the surface of the
workpiece.  A circuit within the probe, e.g. as

5      described in US Patent No. 4,153,998, detects contact
between the stylus 12 and the workpiece, and develops a
trigger signal in response.  The trigger signal is
transmitted to an interface 18, which passes it to a
CNC controller of the machine tool.  This records the

10     X,Y,Z position of the spindle 14 relative to the
workpiece at the time of contact, thereby enabling
dimensional measurements of the workpiece to be made.

Because the probe 10 is to be exchangeable with cutting

15     tools in the spindle 14 of the machine tool, it would
be difficult for its signal to be transmitted via a
hard-wired connection.  Consequently, the probe is
battery powered and has a wireless signal transmission
system.  In the example shown in Fig 1, a radio

20     transmission system is used, and the signal is received
by an antenna 20 connected to the interface 18.
However, other wireless transmission systems for such
probes are well known, including optical and inductive
transmission systems, and these may equally be used.

25     Instead of the touch trigger probe 10, any other kind
of probe may be used, including those mentioned in the
introduction to this specification.

Figs 2 and 3 show more detail of the touch trigger

30     probe 10 shown in Fig 1.  The workpiece-contacting
stylus 12 is connected or connectable to a stylus
holder 22 within a housing 24 of the probe.  The stylus
holder 22 has three radially projecting rollers 26.
These seat kinematically on respective pairs of balls

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28, under the biasing force of a spring 23, thereby
giving the stylus 12 a precisely repeatable rest
position.  When the stylus 12 contacts a workpiece, it
is disturbed from this rest position, breaking an
5    electrical circuit between the rollers 26 and balls 28.
Reference should be made to US Patent No. 4,153,998 for
further details of this and alternative arrangements
which may be used.

10   Electronic circuitry to process the resulting signal is
provided on a flexible printed circuit 30.  As shown,
this may advantageously be wrapped into a triangular
shape, generally coaxial with the stylus 12 and stylus
holder 22, and with the axis of rotation of the spindle
15   14.  The flexible printed circuit 30 can either
surround or be placed above the stylus holder 22.  This
results in a compact arrangement so that the probe can
be built into a small housing 24.  The electronic
circuit includes the components required for processing
20   the trigger signal received from the circuit through
the balls 28 and rollers 26, much of which is
incorporated in a dedicated programmable processor or
microprocessor circuit such as a programmable
integrated circuit (PIC).  It also includes the
25   components necessary for wireless transmission of the
signal to the interface 18.

For simplicity, Figs 2 and 3 show only one of the
components mounted to the flexible printed circuit 30.
30   This is a linear acceleration switch 32.  A suitable
type is commercially available from American Electronic
Components Inc., 23590 County Road 6, Elkhart,
IN 46515, U S A, as part #DD 1284.  Such switches are
also sold as g-switches, i.e. ones which react to g-

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forces. The switch is chosen, amongst other reasons, for its compact size, to facilitate building into the compact arrangement shown in Figs 2 and 3. It incorporates a ball 34 which is biased away from an

5    adjustable contact pin 36 by a spring 38. When the probe undergoes acceleration, the ball 34 makes electrical contact with the pin 36, against the action of the spring 38, closing an electrical circuit.

10   The linear acceleration switch 32 is mounted off the axis of the probe (about which it is rotatable by the spindle 14). This ensures that it reacts not only to linear accelerations, but also to rotation of the spindle 14.

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Since the probe 10 is battery powered, it is desirable to conserve battery life by only switching the probe on when it is required for use. The switch 32 is used to achieve this, in a similar manner to that in US Patent

20   No. 4,599,524. It reacts to the acceleration experienced when the spindle 14 of the machine tool is rotated, and is used to switch the probe circuit to a fully "on" state, from a dormant or quiescent state where it merely monitors the switch 32.

25   Thus, the probe can be turned fully on for normal use after it has been inserted in the spindle 14, by a brief rotation of the spindle 14 under the control of the machine tool's CNC controller.

30   However, in contrast to US Patent No. 4,599,524, the switch 32 reacts not only to accelerations caused by rotation, but also to linear accelerations. For example, it could react to accelerations caused by an automatic tool changer of the machine tool when the

probe is inserted into or removed from the spindle 14;
or to accelerations as the spindle moves normally
around the workpiece; or to movements when the probe is
stored, out of use, in a storage magazine or carousel
5    of the automatic tool changer.  Arrangements to detect
the rotation and to distinguish it from other such
accelerations will now be described with reference to
Figs 4, 5 and 6.

10   Fig 4 shows at 40 the PIC or other processor, which is
chosen to have a low current consumption since it is
permanently connected to a battery 52 or other power
supply located within the probe housing 24.  The PIC 40
is programmed to run a number of routines.  These may
15   for example include digital filtering functions for
processing the trigger signal, as described in our co-
pending International Patent Application No.
WO03/021182.  They may also include functions which
preset modes of operation of the probe, as described in
20   International Patent Application No. WO02/063235.
(International Patent Applications Nos. WO02/063235 and
WO03/021182 are incorporated herein by reference.)

One such mode of operation, which may be preset into
25   the probe during manufacture or upon installation, may
determine whether the probe is to be switched on by the
switch 32 rather than by some other means.  If it is,
then an output 41 of the PIC 40 causes an electronic
switch 56 to apply a supply voltage from the probe's
30   battery 52 to a resistor R1.  As an alternative, the
resistor R1 may receive a supply voltage directly from
the output 41 of the PIC 40.

As shown in Fig 4, the acceleration switch 32 is
connected in series with a resistor R1, across the
battery 52. The switch is connected to an input line
42 of the PIC 40, so that this input is high when the

5   switch 32 is open and low when it is closed. A simple
RC filter, comprising a capacitor C1 and a resistor R2,
filters transient spikes should the switch 32 close
momentarily, e.g. as a result of vibration, and the
resistor R1 limits the current through the switch 32.

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Fig 5 shows schematically one of the program routines
which runs within the PIC 40, called at regular
intervals (every 1ms in the present example). In a
step 44, the input 42 from the switch 32 is polled (at

15  the 1ms intervals) to see whether the input is high or
low. Each time it polls the switch, the routine 44
stores the resulting value in an internal memory.

A step 45 of this routine then analyses the most recent

20  150 such stored values to determine whether or not the
switch was closed on at least 33% of the preceding 150
polls. It sets or clears a flag in the memory on the
basis of this, thus indicating, on a continual rolling
basis, whether the switch 32 has been closed for at

25  least 33% of the preceding 150ms.

This defines a first time interval, with a duration of
150ms, which is chosen because it is approximately the
time taken for one revolution of the probe at a speed

30  of 400 revolutions per minute. Thus, the flag will
remain set if the switch 32 is closed for at least a
third of each revolution of the probe. This has two
effects. First, it filters any contact bounce from the
switch 32. Second, it ensures that the flag will

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remain set, even if the probe is rotated about a
horizontal axis (in a machine where the spindle 14 is
horizontal). In the latter case, the switch 32 may be
opened by the effect of gravity for up to half of each
5    revolution, but the flag will remain set.

Of course, the length of this first time interval could
be varied, e.g. if the probe is to be rotated at a
different speed when it is to be switched on. For
10   example, if it is to be rotated at 1000 revolutions per
minute, the first time interval may be 60ms instead of
150ms. The fraction of this time interval for which the
switch must be closed in order to set the flag could
also be varied - for example it could correspond to a
15   quarter or a half of one revolution.

Fig 6 shows schematically a separate routine 46, which
is also called at regular intervals (e.g. every 1ms) to
poll this flag. It performs an analysis to determine
20   whether the flag has been set (high) continuously for
the preceding 500ms, defining a second time interval,
longer than the first. If so, it provides an output on
a line 48 of the PIC (see Fig 4).

25   The 500ms duration of the second time interval is
chosen to distinguish between deliberate rotation of
the probe 10 and linear accelerations of the types
exemplified above. The linear accelerations typically
do not last as long as 500ms, whereas it is easy to
30   arrange for the probe to be rotated for a period longer
than 500ms. The duration of this second time interval
could of course be greater or less than 500ms,
depending on the duration of the linear accelerations
experienced in practice.

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Thus, the first and second time intervals correspond to
a predetermined signature relating to a specific
movement of the probe (namely, deliberate rotation of
the spindle). The routines of Figs 5 and 6 ensure that
5   the PIC circuit 40 responds to signals from the switch
32 caused by this rotation.

The presence of the output on the line 48 thus
indicates that the switch 32 was operated by the
10   deliberate rotation of the spindle 14, and not by any
other form of acceleration. As seen in Fig 4, it
operates an electronic switch 50 to apply power from
the battery 52 to the heavy power consuming circuits 54
of the probe. These include the circuit through the
15   balls 28 and rollers 26, and the wireless signal
transmission circuit which transmits the probe signal
via an antenna 58 in the probe.

Fig 7 shows a program routine which may be run in the
20   processor 40 as an alternative to the routines of Figs
5 and 6. As with Figs 5 and 6, this routine is called
at regular intervals, e.g. once every 1ms.

The first step 73 of this routine polls the switch 32
25   (at the 1ms intervals). A step 74 then determines
whether the input from the switch is high or low,
indicating whether the switch 32 is open or closed. If
it is closed, a step 76 increments an internal software
register kept in the memory of the processor 40.
30

Irrespective of whether the input from the switch 32
was high or low, in step 78 a software counter is
incremented. A step 80 then tests whether the software
counter has reached a count of 150. The routine only

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proceeds to the further steps shown in Fig 7 if it has
reached 150. If the count is less than 150, the
routine exits (step 81) and takes no further action
until it is called the next time, 1ms later.

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Since it is incremented every 1ms, the counter in steps
78 and 80 indicates whether a first time interval of
150ms has passed. If so, then in a step 82, the
routine checks the count which has been attained by the
10    register which was incremented in step 76. It
determines whether the count in this register is equal
to or greater than 50. If so, this indicates that the
switch 32 has been closed for at least 33% of the 150ms
first time interval, and an internal flag in the memory
15    of the processor 40 is set (step 84). Otherwise, if
the register's count is less than 50, the flag is
cleared (step 86).

It will be appreciated that the steps 74-82, as
20    described so far, could be used as one way of
implementing the process 45 indicated in Fig 5.
However, in the present routine, the flag-setting and
clearing actions taken in steps 84 and 86 differ from
those of Fig 5.

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Specifically, the Fig 7 routine provides not one but
three such flags in the memory of the processor 40.
One of these three flags is set, in turn, each time
step 84 is reached. This is followed by a step 88,
30    which determines whether all three flags have been set
in succession, on the last three successive passes of
the step 84. If not, the routine merely exits at step
92 and takes no further action until it is next called
1ms later.

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If there have been three flags in succession, step 90
outputs a signal on line 48 of the processor 40, to
switch on the probe circuits 54 (see Fig 4). The
routine then exits via step 92. Thus, the result is

5  similar to that of the routine of Fig 6, except that
instead of a single time period of 500ms it is
determined whether flags have been set for three
successive periods of 150ms (making a total of 450ms).
As in Fig 6, this provides a second time interval,

10 longer than the first, which distinguishes between
deliberate rotation of the probe 10 and linear
accelerations.

If, in step 82, it is determined that the register has

15 not exceeded a count of 50 during the 150ms first time
interval, then the step 86 clears all three of the
flags. This indicates that the 450ms second time
interval has not been achieved, so no further action is
required. The routine again exits via step 92.

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Whenever the routine exits via step 92, it is necessary
to zero the register and the counter, ready for future
incrementing in the steps 76 and 78. This starts a new
150ms first time interval, the next time the switch 32

25 is polled in step 44.

Again, it will be seen that the various time intervals
correspond to a predetermined signature relating to a
specific movement of the probe, i.e. deliberate

30 rotation of the spindle. The routine of Fig 7 again
ensures that the PIC circuit 40 responds to signals
from the switch 32 caused by this rotation.

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After the heavy power consuming circuits 54 have been
switched on, it is also desirable to switch them off
when use of the probe has finished.  The method by
which this is to be done may be one of the modes of

5      operation which is pre-programmed into the probe and
stored in the memory of the PIC 40, as described in the
above-mentioned International Patent Application No.
WO02/063235.  One such method is to detect a further
deliberate rotation of the probe in the spindle 14.  An

10     alternative is for the probe to time out after a
predetermined period of non-use.

Fig 8 shows a routine which runs at regular intervals
in the PIC 40 for this purpose.  This routine only runs

15     when the probe circuits 54 have been switched on (i.e.
line 48 is high).  That condition is determined in an
initial step 60, and if it is false the routine simply
returns without performing any of the following steps.

20     In the next step 62, the routine checks the pre-
programmed mode of operation, stored in the memory of
the PIC 40.  It determines if a "spin-off" mode has
been pre-programmed, i.e. whether the circuits 54 are
to be switched off by a further rotation of the probe.

25     If the answer is yes, it proceeds to a step 64.  In
step 64, it waits for a further rotation of the probe,
determined as in Figs 5 and 6 or Fig 7.  Meanwhile,
normal operation of the probe continues.  When such a
further rotation is detected, the circuits 54 are

30     switched off by taking the line 48 of the PIC low (step
66).

If it is determined in step 62 that the probe is not in
the "spin-off" mode, then the circuits 54 are instead

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switched off by a "time-out" mode. Here, a step 68
determines the pre-programmed duration of the time-out
interval, e.g. 12s,33s and 124s. This is a pre-
selectable value, as previously stored in the memory of
5    the PIC 40 in accordance with International Patent
Application No. WO02/063235.

Next, in step 70, the routine waits for the specified
time-out interval. Meanwhile, normal operation of the
10   probe continues, as in step 64. The time-out interval
starts from when the probe circuits 54 were turned on.
Advantageously, however, the time-out interval may be
re-started each time the probe generates a trigger
signal. This ensures that the probe circuits 54 are
15   not switched off during an extended period of use of
the probe. When the time-out interval expires, the
circuits 54 are switched off by taking the line 48 of
the PIC low (step 72).

20   Although not shown in Fig 8, even in the "spin-off"
mode it can be desirable to provide a long time-out
interval, e.g. 90 minutes, to ensure that the probe
circuits 54 are eventually switched off even if no
further rotation of the probe is detected in step 64.
25

In place of the switch 32 shown in Figs 2 and 3, other
acceleration-sensitive switches or sensors may be used.

For example, a mercury switch may be used. It may be
30   normally closed, opening when acceleration takes place
(in contrast to the normally open switch 32). Step 45
of Fig 5 should then check to see if the switch has
been opened, rather than closed. Technically such an

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arrangement works well, but mercury switches have
environmental disadvantages.

Alternatively, linear acceleration switches formed from
5    micro-machined silicon (MEMS) may be used.  As
previously mentioned, another alternative is to use an
accelerometer which provides a signal proportional to
the acceleration, with appropriate processing of the
signal provided either electronically or by software in
10   the PIC 40.  Piezo or strain gauge sensors may be used.

Fig 9 illustrates a further embodiment of the
invention.  The probe is fitted with one or more
acceleration sensors 132. Preferably there are at least
15   two, arranged at right angles in the probe so as to be
responsive to movements on two orthogonal axes X and Y.
There may optionally be a third such sensor 132,
arranged at right angles to both the other two, so as
to be responsive to movements in the Z direction (i.e.
20   the axis of rotation of the spindle).

The sensor(s) 132 may be the same as the acceleration-
sensitive switch 32 in Figs 2 and 3, or may be another
type of acceleration-sensitive sensor as discussed
25   above. Particularly in the latter case, signal-
conditioning circuits 100 may be necessary to process
the signals to a form where they can be fed to a
programmable microprocessor or PIC 140, corresponding
to the PIC 40 in Fig 4.
30
The sensor(s) 132 provide (optionally via the signal-
conditioning circuits 100) a signal or signals 102
which relate to the movements and accelerations which
the probe undergoes.  These include the movements and

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accelerations which the probe undergoes during a tool
change operation, as it is removed from a tool carousel
of the machine tool and inserted into the machine tool
spindle.  Since those movements and accelerations are
5    the same, for a given machine tool, the signal or
signals 102 form a signature which is unique to the
tool change operation.

The action of tool changing (inserting the probe into
10   the spindle prior to use) is therefore learned by the
PIC 140, by storing the corresponding signature signal
or signals 102 from the sensor or sensors 132 in a
flash memory 104.  This is done by performing one of
more such tool changes in a learning step when the
15   probe is installed on the machine tool.

During subsequent use, the PIC 140 monitors the
signal(s) received from the sensor(s) 132.  When they
match the stored signature signal(s), to a suitable
20   tolerance, an output is provided on a line 148,
corresponding to the line 48 in Fig 4.  This connects
the battery power supply to the remaining circuits of
the probe.  It will be seen that this discriminates
between the movement of the probe during the tool
25   change operation and other movements of the probe.

The signature signal(s) 102 are shown in Fig 9 as being
of rectangular form, so that they may be stored in the
memory 104 in terms of the durations of the high and
30   low parts of the waveform.  However, if a sensor or
sensors 132 is used which provides outputs proportional
to acceleration, these may be digitised by an analogue
to digital converter, provided in place of the signal-

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conditioning circuit 100. The signature may then be
stored in the memory 104 as a digital representation.

Alternatively, the one or more sensors 132 may be

5    vibration sensors which provide output(s) responsive to
the vibrations which occur during the movements of the
probe in a tool change operation, and particularly when
the shank 16 of the probe is brought into contact with
the mating parts of the spindle 14. Again, this will

10   be unique to a given machine tool, and so the vibration
signature may be learned and used in the same way as
above. It will be appreciated that this arrangement
discriminates the movements indirectly, as a result of
the vibrations caused.

15
Whichever form of such signature recognition is used,
the probe circuit may be disconnected from the battery
in any of the ways discussed for the previous
embodiments, e.g. a timeout after a period of

20   inactivity. If it is desired to use motion or
vibration detection to disconnect the battery, then a
second signature signal (or a set of signature signals
from each sensor 132) should be learned and stored in
the memory 104, corresponding to the movement of the

25   probe when it is removed from the spindle and returned
to the tool carousel.

In place of sensors 32, 132 specifically provided to
react to movement or vibration, it is possible in any

30   of the above embodiments to make use of the sensors
which are already normally provided in a probe, to
sense the workpiece. For example, in the case of a
probe according to US Patent 4,153,998, vibration or
movement during a tool change operation can cause

unseating of the electrical contacts which normally indicate contact of the probe's stylus with a workpiece surface. Alternatively, in an analogue or measuring or proportional probe, the sensors for the X,Y,Z movement

5    of the stylus can act as accelerometers. In either case, if these sensors are permanently connected to the battery, they can be used to provide signature signals which the PIC 140 in Fig 9 can learn and detect. The output on line 148 can then be used to turn on the

10   signal transmission circuits of the probe, which are normally the heaviest consumers of power.